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A Qualitative Meta Analysis Review on Medical Image Registration Evaluation

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Abstract

How to estimate the results of medical image registration is still a problem, because of no "golden estimation criterion". In this paper, a qualitative meta analysis method is applied to analyze medical image registration performance evaluation based on the recent published literature, presenting an overview of existing estimation statistics criteria for medical image registration. At last, a summary of some problems still existing in this field is given out, which may be the hot in the future.

Keyword: image registration; registration evaluation; performance assessment; meta analysis; medical images

1. Introduction

Image registration is of great importance in image engineering, and it arises and develops with the expanded applications of various imaging techniques. Registration is a problem of major interest in almost all applications in medical image processing, which is now an indispensable technique for disease diagnosis and neuroscience research. Multimodality image registration, combining information from different imaging modalities into a single image, can facilitate correct images to be applied as the guidance in intra-operative operation. Monomodality registration, concerning proper visualization of useful image information, is always the first step in successful visualization and quantification of temporal changes in anatomy and physiology [1~2].

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The essence of image registration can be described as an optimization process which minimizes the difference between the two set of images. Various approaches to medical image registration have been proposed in the past several decades, falling into three main categories: the point-based algorithms, surface-based algorithms and volume-based algorithms. In general, point-based registration algorithms may result in inaccuracies and inconsistencies of image registration because of the low resolution along the longitudinal axis, the small number of corresponding markers, and inaccuracies in their placement or identification. Surface-based registration algorithms depend on a reliable and accurate surface segmentation, which is difficult to achieve in an easy and real-time way. However, volume-based registration algorithms involve the optimization of some similarity measures calculated directly from the voxel values [3].

In contrast to the great number of literature concerning on special image regisrtation algorithms, there is few references about the registration evaluation or performance assessment, which is still a challenging, open and application-dependent problem. According to whether the ground truth is needed, the registration evaluations can be classified into two categories: ground truth based methods and methods without ground truth. The remarkable difference between these two categories is that the ground truth data are obtained by placing fiducial markers before, manually selecting tie-points, simulating gold standard data from the registered images or being produced with some specific equipments, etc [4].

Meta analysis is a method of research synthesis used to integrate and interpret empirical research studies and to summarize the results in a standardized format. A qualitative meta analysis is a type of structured qualitative study which uses as data the findings from other qualitative studies linked by the same or a related topic [5~6]. In this paper, we use qualitative meta analysis methods to analysis medical image registration evaluation based on the recent published literature.

2. Methods

Qualitative studies published between January 2007 and July 2011 that discussed the image registration evaluation and performance assessment are included in the analysis. The Entrez–PubMed database and CNKI database are searched using the keywords “image registration, registration evaluation and perormance assessment”.

The evaluation criteria suggested by Aitkins et al. [5, 7] are used primarily to assess the identified studies, seen in Table 1. In addition to the quality assessment, reduplicate reports and studies without concrete evaluation index are excluded. The final data set comprises 8 articles of sufficient quality that addressed factors for the successful evaluation methods.

Table 1. Criteria used to select publications to be included in the qualitative meta-analysis

Study Evaluation Criteria
Is this study qualitative research?
Are the research questions clearly stated?
Is the qualitative approach clearly justified?
Is the approach appropriate for the research question?
Is the study process clearly described?
Is the role of the researcher clearly described?
Is the method of data collection clearly described?
Is the data collection method appropriate for the research question?
Is the method of analysis clearly described?
Is the analysis appropriate for the research question?
Are the claims made supported by sufficient evidence?

3. Results

In the synthesis and analysis, all the 8 studies are summarized in Table 2, from the respectives of authors, year, country, research objective and evaluation statistics, respectively.

Table 2. Factors identified for every publication

Authors	Year	Country	Research Objective	Evaluation Statistics
Avants Brian B et al [8]	2011	USA	Report evaluation results on cortical and whole brain labels for both the affine and deformable components of the registration.	squared intensity difference; cross-correlation; voxel-wise mutual information
Pawiro Supriyanto et al [9]	2010	USA	Propose a new gold standard data set using a pig head with attached fiducial markers for the validation of 2D/3D image registration algorithms.	projection distance errors (PDE); target registration errors (TRE)
Wei Ying et al [10]	2010	USA	Report the analysis and comparison of five non-rigid image registration algorithms (Affine, AIR, Demons,SLE and SICLE)	relative overlap; intensity variance; normalized ROI overlap; alignment of calcarine sulci; inverse consistency error; transitivity error
Ito Koichi et al [11]	2009	Japan	Propose a performance evaluation method using Mandelbrot fractal set	root mean square
Zhang Yunkai et al [3]	2009	USA	Evaluate 4 volumed-based automatic image registration algorithms from two commerically available treatment planning systems (Pillips Syntegra and BrainScan)	cross correlation; local correlation; normalized mutual information; BrainScan mutual information
Shen Jiankun et al [12]	2008	UK	Evaluate a flexible spring mass system image registration technique against the Demons and the B-spline Free Deformations	distance error histogram
Shu Lixia et al [4]	2007	China	Propose an evaluation approach based on the registration curves	ratio of half amplitude to half-bind width; curvature variation
Wei Chunrong et al [13]	2007	China	Analyze and assess the performance on image registration algorithms based on contour extraction and mutual information	root mean square; cross entropy

We can draw conclusions as following from Table 2:

1) Mutual information (MI) is currently a popular registration statistics method to scale the similarities between two image sets and for convenience of calculation and analysis. From the abundant literature, it is clear that MI lives up to its reputation of being a general applicable measure and it can be used without any preprocessing, user initialization or parameter tuning. However, from the conclusions of certain comparison studies and from the interest in adaptations of the measure, it can be inferred that MI may not be a universal effective measure for all registration situations. An obvious drawback of mutual information is that the dependence of the gray values of neighbor pixels is ignored. Such situations arise when the images are of low resolution, when the overlapping part of the images is too small or as a result of interpolation methods. A possible solution to failure of MI can be reduced to spatial information, something that is not contained in the measure. On the other hand, when monomodality registration using MI, failures or poor results are often found in that there are many local maxima in MI measure function, which cause problems with optimizer and lead to misregistration.

2) In reference [8], the results indicate that the Demons registration algorithm produces the best registration results with respect to the relative overlap statistic; however, it produce nearly the worst registration results with respect to the inverse consistency statistic. This interesting fact illustrates the need to use multiple evaluation statistics to assess the algorithm performance comprehansively.

3) Generally when the algorithms are estimated, more attention is paid on precision, stability, reliability, complexity and usability, especially on the first two parameters. The published 8 references are evaluation registration performance from parameters aspect. Except for these, robustness and speed are the two important factors for image registration algorithms. The robustness here means the ability to retrieve reasonable results from different initial conditions. It depends on many factors, such as anatomical information of images, initial conditions, modalities, and algorithms.

4. Conclusion

In this paper, we use qualitative meta-analysis methods to analyze medical image registration evaluation based on the recent published literature, mainly from the evaluation statics aspects. At present, there are still several problems existing on estimating methods [14]:

1) A large number of parameters or algorithm design choices, both subtle and obvious, are selected by relying upon experience and good engineering principles, but without direct evaluation.

2) There is still a long way to make good use of these methods and parameters to find a way to estimate an algorithm from all sides.

3) The algorithms can not only be estimated by parameters and subjective estimation by experts, but also from algorithms characteristics, such as anti-noise performance, practicality, and so on.

4) The conclusions drawn by this paper are still far from perfect for the lack of sufficient publications.

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